AD_____

Award Number: DAMD17-01-1-0818

TITLE: Ethnic and Environmental Influences on Vitamin D Requirement in Military Personnel

PRINCIPAL INVESTIGATOR: Robert P. Heaney, M.D.

CONTRACTING ORGANIZATION: Creighton University
Omaha, NE 68178

REPORT DATE: September 2007

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01-09-2007	Final	1 Oct 2001 – 29 Aug 2007

4. TITLE AND SUBTITLE

Ethnic and Environmental Influences on Vitamin D Requirement in Military Personnel

5a. CONTRACT NUMBER

5b. GRANT NUMBER
DAMD17-01-1-0818

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Robert P. Heaney, M.D.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Creighton University
Omaha, NE 68178

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The purposes of this study are to provide quantitative estimates of 1) the effective amount of vitamin D produced in the skin as a function of skin pigmentation; and 2) the rate of utilization of vitamin D as a function of ethnicity. The outcome consist of estimates of the amount of vitamin D that must be given orally to military personnel of different races and in different assigned locations so as to ensure and maintain normal vitamin D status.

15. SUBJECT TERMS
Vitamin D; race; skin color

16. SECURITY CLASSIFICATION OF:				18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					USAMRMC
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
U	U	U	UU	13	

Table of Contents

INTRODUCTION

The purposes of this project were to examine relationships between ethnic/racial identity, skin pigmentation, and vitamin D status. To accomplish this aim, we designed and carried out experiments to determine the following:

- doses of oral vitamin D that must be given to supplement solar inputs so as to achieve desired vitamin D status (see Work Performed: Experiment 1), and
- quantitative effects of skin exposure to sunlight on vitamin D status (see Work Performed: Experiment 2),

specifically as each applies to personnel of differing ethnic/racial identity and skin pigmentation.

Despite recruitment and compliance challenges, we accomplished our stated objectives, and in fact exceeded enrollment targets. This is the final report on the above-referenced award.

BODY OF REPORT

Work Performed: Project 1

The work of Project 1 examined ethnic/racial differences in metabolism of known inputs of cholecalciferol (vitamin D_3). This work took place during months (October through March) when vitamin D production from sun exposure is minimal at Omaha's latitude (41.3° N). In the 2002-03 work, subjects were randomized to a no-treatment group (Group 1) or to vitamin D_3 at an oral dose of 1,000 IU/d[1] (Group 2). In the 2003-04 work, subjects were randomized to vitamin D_3 at oral doses of 5,000 (Group 3) or 10,000 IU/d (Group 4) over periods averaging 112 days. A total of 94 ostensibly healthy adults participated. As Table 1 shows, they completed a total of 437 study visits.

Table 1. Study visits by Treatment Group

		Group 1	Group 2	Group 3	Group 4
	@ wk	0 IU/d	1000 IU/d	5000 IU/d	10000 IU/d
Visit 1	0	24	26	20	24
Visit 1a	2	0	0	0	23
Visit 2	4	22	22	19	24
Visit 3	8	20	22	19	23
Visit 4	12	19	22	19	22
Visit 5	16	18	21	12	13
Visit 6	19	0	0	1	2
Column totals		103	113	90	131
Grand total		437			
		from 10/3/2002 to 3/19/2003		from 10/22/2003 to 3/15/2004	

[1] Each International Unit = 0.025 μg of cholecalciferol

The subjects allocated to vitamin D_3 at 10,000 IU/d had an extra visit at 2 weeks (labeled Visit 1a in Table 1) for measurement of serum calcium.

Our earlier work in this area, which took place from 1996 to 2000, involved subjects who were nearly all non-Hispanic whites [1,2]. In the effort reported here, we aimed to study subjects of color; Table 2 displays participants by sex and self-identified ethnic/racial group.

Table 2. Subjects by Sex and Self-Identified Ethnic/Racial Group

				Totals	
		Women	Men	*N*	percent
Black, not Hispanic		50	15	65	69.1%
Hispanic		10	3	13	13.8%
White, not Hospanic		12	4	16	17.0%
Other		0	0	0	0.0%
Totals	*N*	72	22	94	100.0%
	percent	76.6%	23.4%	100.0%	

Table 3 displays baseline data for all participants in Project 1. For serum vitamin D_3, entries of 0.5 ng/mL indicate levels at or below the lower limit of measurability. Urine calcium-to-creatinine ratio was determined in 2-hour specimens collected after an overnight fast. Total-body bone mineral and body composition were determined by dual-energy x-ray absorptiometry (DXA). All measurements and assays were carried out by standard methods.

Table 3. Descriptive Data

	*All groups**								*Groups 3 & 4 only**			*Subjects from all groups***			
									Serum	*2h fasting Urine*		*Data by DXA*			
	Age	*Ht*	*Wt*	*BMI*	*Tx per*	*25(OH)D*	*Vit D_3*	*PTH*	*Ca*	*Ca/Crt*	*Na/Crt*	*TBBM*	*Fat*	*Lean*	*Fat*
	y	*m*	*kg*	*kg/m^2*	*d*	*nmol/L*	*ng/mL*	*pg/L*	*ng/mL*	*g/g*	*mEq/g*	*g*	*kg*	*kg*	*%*
N	94	94	94	94	94	94	93	94	44	44	44	77	77	77	77
median	41.1	1.663	78.8	28.8	112	43.1	0.5	38.3	9.2	0.045	104.9	2335	25.9	51.1	32.7
inter-	31.9	1.610	70.5	25.0	85	33.0	0.5	30.5	8.9	0.027	52.1	2091	19.2	47.1	26.3
quartile	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to
range	47.4	1.731	90.8	31.8	115	57.4	0.5	52.0	9.5	0.094	144.7	2509	32.6	58.5	38.5

*Measurements made at baseline **Measurements made midway during the treatment period

Figures 1 through 4 (below and on the next page) display changes in serum 25(OH)D for each subject with more than 2 datapoints, by treatment group.

Fig 1

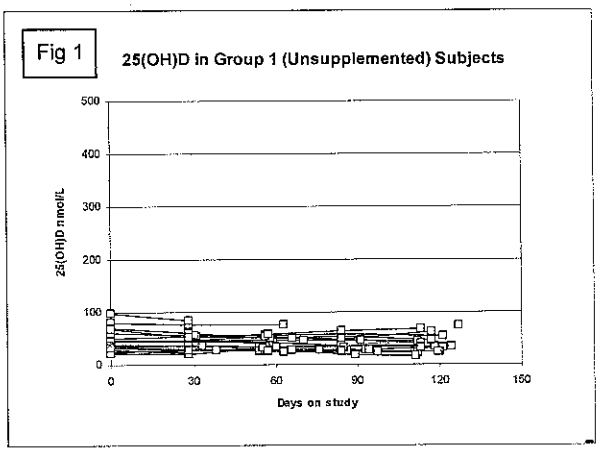


Fig 2

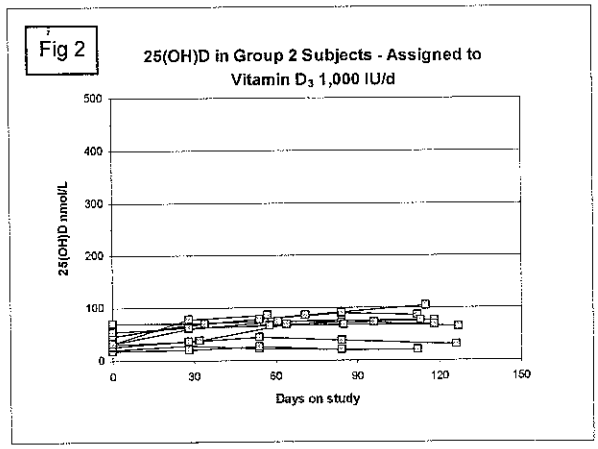


Fig 3

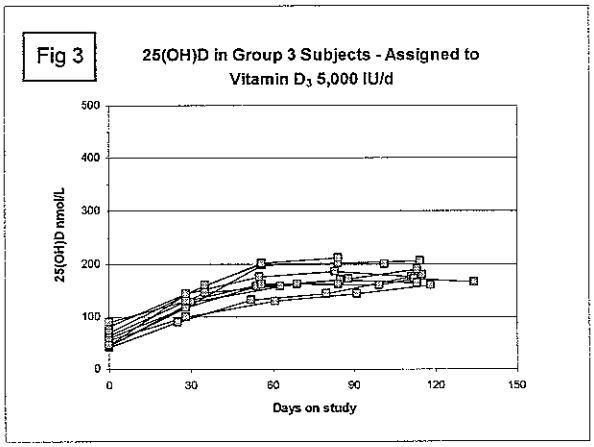


Fig 4

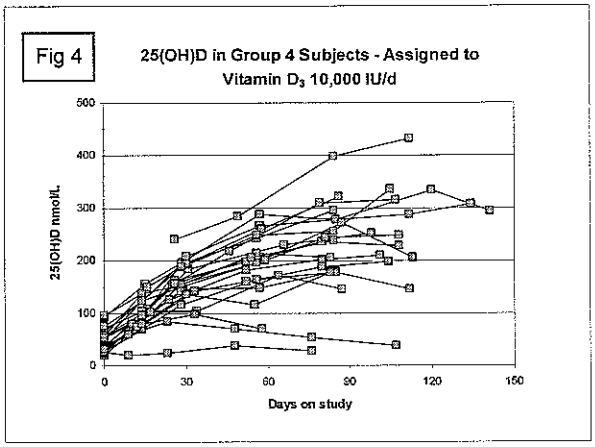


Table 4 displays aggregate treatment-related data by Group. The figures above and Table 4 were created without regard to subject compliance.

Table 4. Treatment effects by Group

Group 1	25(OH)D nmol/L			Vit D_3 ng/mL	PTH pg/L			
No Tx	Base	Max<base	Max>base	Max=base	Base	Min*	Max**	Ind****
N=23***		*N*=13	*N*=10	*N*=21				range
median	36.4	-9.6	2.5		32.4	25.0	44.9	17.1
inter-	31.5	-10.9	1.0		24.3	22.4	38.7	12.6
quartile	to	to	to		to	to	to	to
range	48.2	-6.2	4.8		43.4	36.0	57.2	23.5

Group 2	25(OH)D nmol/L			Vit D_3 ng/mL		PTH pg/L			
1,000 IU/d	Base	Max**	Increm*****	Base	Max**	Base	Min*	Max**	Ind****
N=26***				not > 0.5					range
				N=25					
median	36.1	72.4	27.1		5.9	38.5	30.9	50.5	17.9
inter-	32.3	53.1	10.2		0.6	33.9	25.6	43.2	13.3
quartile	to	to	to		to	to	to	to	to
range	51.6	85.0	40.0		7.4	49.6	34.6	55.6	24.3

Group 3	25(OH)D nmol/L			Vit D_3 ng/mL		PTH pg/L			
5,000 IU/d	Base	Max**	Increm*****	Base	Max	Base	Min*	Max**	Ind****
N=19***				not > 0.5					range
	N=20			*N*=18		*N*=20			
median	48.0	174.2	109.6		32.7	41.3	31.4	50.3	18.1
inter-	43.7	157.4	81.0		25.0	34.4	23.6	43.9	14.8
quartile	to	to	to		to	to	to	to	to
range	60.3	188.8	138.6		41.0	47.8	38.4	55.9	21.3

Group 4	25(OH)D nmol/L			Vit D_3 ng/mL		PTH pg/L			
10,000 IU/	Base	Max**	Increm*****	Base	Max	Base	Min*	Max**	Ind****
N=24***				not > 0.5					range
				N=22					
median	40.3	236.8	179.6		59.4	38.5	25.6	51.5	21.3
inter-	33.6	178.1	133.6		41.5	31.5	22.6	34.5	15.5
quartile	to	to	to		to	to	to	to	to
range	59.7	310.3	249.1		68.7	59.0	34.1	63.8	30.7

** min = each subject's lowest measured values*

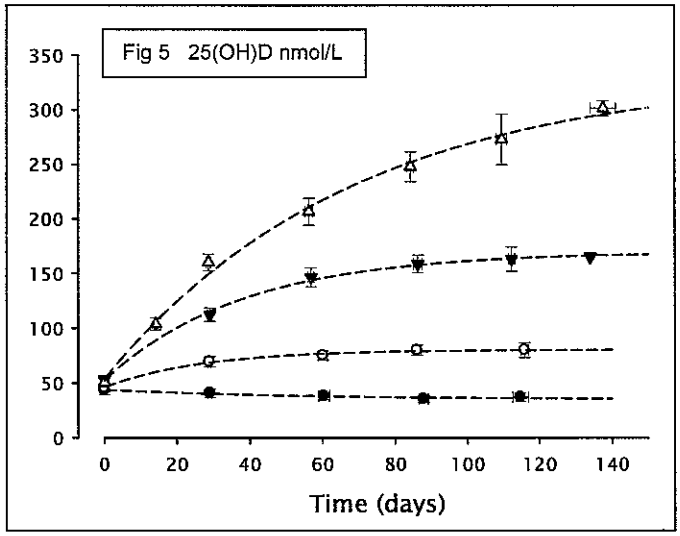
*** max = each subject's highest measured values*

****unless shown otherwise for specific cells*

*****Individual range = each subject's highest less lowest values*

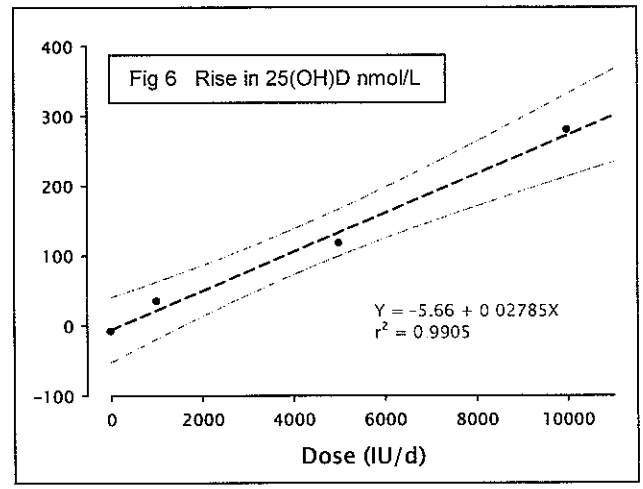
******Increment = each subject's maximum less baseline values*

Figure 5 plots the mean changes for all four treatment groups (with, as expected, the 10000 IU/d dosage group uppermost and the no-treatment group nearest the bottom), fitted to the same function as we employed earlier for groups largely made up of non-Hispanic whites [2]. Note the rise to maximum for each treatment group (actually a fall for the zero-dose group)



The function was as follows, $Y = Y_0 + a(1-e^{-bt})$, in which the parameter "a" is the rise from baseline to the new steady state equilibrium value, i.e., the amount of increase in serum 25(OH)D that would be achieved and sustained if the particular dosage rage were to be continued indefinitely.

Figure 6 plots the mean "a" values as a function of dose and shows an essentially linear increase, as we previously reported [2]. In the present work, the slope was +0.02785, which means that serum 25(OH)D would be predicted to rise by about 2.785 nmol/L for every 100 IU of vitamin D_3 taken as a daily oral supplement.



This quantitative information also permits estimation of the average dose required to raise serum 25(OH)D by any desired amount. Thus, subjects with baseline 25(OH)D values of ~50 nmol/L would require a daily oral supplement of ~1080 IU/d of vitamin D_3 to raise serum 25(OH)D to ~80 nmol/L and to sustain that level. Note that this daily oral supplement of ~1080 IU/d would have to be over and above all these subjects' usual sources of vitamin D – solar, dietary, and supplemental – which, after all, had supported 25(OH)D values of only ~50 nmol/L. That this estimate is essentially correct is shown graphically in Figure 5 for the 1000 IU/d dose group, whose achieved 25(OH)D value at the end of winter was just shy of 80 nmol/L.

For subjects who participated in the 2003-04 work (i.e., Groups 3 and 4, assigned to 5,000 and 10,000 IU/d, respectively), we were able to employ an objective measure of skintone. We used a portable tristimulus colorimeter (IMS SmartProbe-400, IMS Inc., Milford, CT). This handheld instrument employs the standard CIE color system[2] We used readings on the black-white axis of this color system (lightness or "L" readings) as an index of melanin skin pigmentation; each subject's "L" value at a site not exposed to sunlight (i.e., upper inner arm), useful as a measure of constitutive (inherent and untanned) skintone. Table 5 displays subject identity by constitutive skintone, using (objective and reproducible, though arbitrary) skintone categories derived from the Human Skin Tone Chart (IMS Inc., Milford, CT).[3] Mean values of our "L" readings of the first 3 standards were used to define a "lightest skintone" range, for the next three an "intermediate skintone" range, and for the last three a "darkest skintone" range.

Table 5. Sex, Self-identified Race/Ethnicity, and Treatment Group by Constitutive Skintone*

	Lightest		Intermediate		Darkest	
"L" readings**	56.5 or more		56.4 to 37.9		37.8 or less	
	Grp3	Grp 4	Grp3	Grp 4	Grp3	Grp 4
Women						
Black	1	2	9	6	2	5
Hispanic	1	4	1	--	--	--
White	--	1	--	--	--	--
Other	--	--	--	--	--	--
Men						
Black	1	1	2	3	1	1
Hispanic	1	--	--	--	--	--
White	--	--	--	--	--	--
Other	--	--	--	--	--	--

*See test for details
**Lightness readings by IMS SmartProbe-400 taken at a site not exposed to sunlight (e.g., upper inner arm)

Table 6a displays findings by these same three ranges, with descriptive data combined for Groups 3 and 4 and treatment induced values for each group separately.

Table 6a. Baseline and Treatment Induced Values for Subjects by Constitutive Skintone
"L" groups follow Human Skintone Chart (IMS, Inc., Milford CT), all values are medians

Groups 3 & 4		"L"	Age	Ht	Wt	BMI	TBBM	Fat	25(OH)D	PTH	CaCrt	NaCrt
"L" reading	N	range	y	m	kg	kg/m^2	g	%	nmol/L	ng/mL	g/g	meq/g
Lightest	12	56.5 or more	41.5	1.650	70.4	25.4	2346	31.9	65.0	39.1	0.098	128.3
Intermediate	21	56.4 to 37.9	41.2	1.691	78.6	28.0	2431	35.0	45.3	45.6	0.041	99.7
Darkest	9	37.8 or less	38.0	1.681	79.9	27.6	2335	28.2	42.7	31.9	0.052	60.6

Group 3 - 5,000 IU/d		max*	max*	min**
"L" reading	N	25(OH)D	Vit D_3	PTH
Lightest	4	168.1	37.5	30.4
Intermediate	12	181.9	30.8	37.7
Darkest	3	171.8	30.4	21.0

Group 4 - 10,000 IU/d		max*	max*	min**
"L" reading	N	25(OH)D	Vit D_3	PTH
Lightest	8	236.8	62.6	29.2
Intermediate	9	209.5	58.3	26.3
Darkest	6	289.9	41.8	23.8

* max = median of each subject's highest measured values
** min = median of each subject's lowest measured values

[2] The 1976 Commission Internationale d-Eclairage (CIE) L*a*b color system has three color axes: light-dark (L*), red-green (a*), and blue-yellow (b*). See Adobe Systems online technical guide.

[3] The Human Skintone Chart is a set of 9 stable ceramic color samples, sequentially decreasing in "L" value and mounted on cardstock in 3 rows of 3. Repeated readings of each standard over time was used to assure instrument stability

Table 6b arranges these data by self-identified race/ethnicity, with median "L" readings for each racial/ethnic group.

Table 6b. Baseline and Treatment Induced Values for Subjects by Self-identified Race/Ethnicity
All values are medians

Groups 3 & 4		"L"	Age	Ht	Wt	BMI	TBBM	Fat	25(OH)D	PTH	CaCrt	NaCrt
	N	reading	y	m	kg	kg/m^2	g	%	nmol/L	ng/mL	g/g	meq/g
White	1	69.9	37.7	1.680	76.5	27.1	2435	34.6	95.4	22.1	0.098	143.9
Hispanic	7	61.6	41.6	1.596	71.0	29.2	1981	35.2	57.1	45.4	0.045	107.4
Black	35	51.2	41.2	1.697	79.9	27.6	2440	31.0	44.0	38.3	0.045	99.7

Group 3 - 5,000 IU/d		max*	max*	min**
	N	25(OH)D	Vit D_3	PTH
White	0	- -	- -	- -
Hispanic	3	155.9	37.7	31.4
Black	16	177.5	31.8	29.7

Group 4 - 10,000 IU/d		max*	max*	min**
	N	25(OH)D	Vit D_3	PTH
White	1	213.3	73.8	16.4
Hispanic	4	244.5	56.1	38.9
Black	19	237.2	58.3	25.5

** max = median of each subject's highest measured values*
*** min = median of each subject's lowest measured values*

Comment – Reportable Outcomes – Project 1

- Subjects in the present study, predominantly self-identified as non-white (as shown in Table 2), showed a pattern of response to daily oral dosing with vitamin D_3 that did not differ significantly from that reported earlier among predominantly white subjects. In other words, for any given oral dose of vitamin D_3, the 25(OH)D response is the same regardless of ethnicity

- Baseline values for serum 25(OH)D, collected in October and November, had a mean value of only 47.4 nmol/L[4], as compared to a mean of 70.3 nmol/L for predominantly white subjects tested at the same time of the year [2].

- Objective measurement of constitutive (inherent and untanned) skintone provides a potentially useful method for identifying persons at risk of poor vitamin D status, and appears to perform better than self-identified skin color or ethnicity.

- Although serum values for both 25(OH)D and vitamin D_3 rose among all groups assigned to vitamin D_3 (as shown in Table 4), there was, as expected, no obvious effect on parathyroid hormone levels.

- Of 221 measurements of serum calcium from subjects in Groups 3 and 4 (assigned to vitamin D_3 5000 and 10000 IU/d), a single value of 10.6 mg/dL exceeded the accepted reference range[3]; the same subject's value was 9.4 mg/dL, well within the reference range, at the next visit.

[4] The mean baseline 25(OH)D was calculated for this comparison; non-parametric data are presented in Table 3.

Work Performed: Project 2

The work of Project 2 examined ethnic/racial differences in the serum 25(OH)D response (and its physiological correlates) to summer sun exposure among outdoor workers with a wide range of skin pigmentation. We collected paired data from end-of-summer (Visit 1) and end-of-winter (Visit 2). Three subjects returned for a third visit a full year after Visit 1. A total of 87 ostensibly healthy adults participated. As Table 7 shows, they completed a total of 163 study visits.

Table 7. Study visits	
Visit 1	87
Visit 2	76
Total	163
from 8/29/02 to 2/29/07	

Table 8. Subjects by Sex and Self-identified Ethnic/Racial Group

				Totals	
		Women	Men	*N*	percent
Black, not Hispanic		13	29	42	48.3%
Hispanic		4	6	10	11.5%
White, not Hispanic		13	18	31	35.6%
Other		2	2	4	4.6%
Totals	*N*	32	55	87	100.0%
	percent	36.8%	63.2%	100.0%	

Table 8 displays participants by sex and self-identified ethnic/racial group. Note that these subjects were more diverse than those recruited for Project 1.

Table 9 presents descriptive data and seasonal findings for all subjects. As in earlier work [1], we used seasonal differences in 25(OH)D as estimates of summer increment (increases related to summer sun exposure). We used the "rule of nines" (see standard texts dealing with burn assessment) to estimate the percent of body surface area exposed to sunlight (see BSA in Table 9) according to each subject's usual outdoor attire [1].

Table 9. Descriptive Data and Seasonal Findings - All Subjects

	Age	Ht	Wt	BMI	TBBM	Fat	Lean	Fat	BSA*	Visit Intrvl
	y	m	kg	kg/m2	g	kg	kg	%	%	d
N	87	86	86	86	86	76	76	76	82	76
median	35	1.724	81.4	27.2	27.2	20.6	61.7	24.5	43.0	158
inter-quartile range	27 to 44	1.651 to 1.793	66.4 to 94.4	23.4 to 31.5	23.4 to 31.5	14.5 to 26.3	50.1 to 71.2	18.3 to 31.6	28.3 to 53.0	147 to 170

	25(OH)D nmol/L			Vit D_3 ng/mL		1,25(OH)2D pg/mL		PTH pg/mL	
	end smr	end wtr	increm**	end smr	end wtr	end smr	end wtr	end smr	end wtr
N	87	78	76	87	76	87	78	87	78
median	65.7	46.8	24.4	1.0	1.0	33.6	35.4	28.6	37.0
inter-quartile range	50.8 to 100.1	29.1 to 67.5	14.7 to 34.4	0.5 to 3.8	0.5 to 1.0	30.2 to 44.1	31.1 to 43.3	24.4 to 38.5	27.0 to 47.9

	serum Ca mg/dL		Ca AbsFx		urine CaCrt g/g		urine NaCrt mEq/g	
	end smr	end wtr	end smr	end wtr	end smr	end wtr	end smr	end wtr
N	87	78	87	78	87	78	87	76
median	9.5	9.5	0.304	0.295	0.071	0.046	95.2	74.4
inter-quartile range	9.1 to 9.8	9.1 to 9.8	0.260 to 0.365	0.233 to 0.342	0.035 to 0.094	0.027 to 0.086	62.9 to 134.4	51.5 to 117.6

**sun=exposed body surface area*

***Increment = estimated gain in 25(OH)D attributed to a summer season of sun exposure*

Table 10 displays subject identity by constitutive skintone, with the same layout as employed for Table 5. The "L" reading was not available for 1 female subject.

Table 10. Sex and Self-identified Race/Ethnicity by Constitutive Skintone

	Lightest	Intermediate	Darkest
"L" readings*	56.5 or more	56.4 to 37.9	37.8 or less
Women			
Black	--	8	4
Hispanic	3	1	--
White	9	4	--
Other	--	2	--
Men			
Black	--	9	20
Hispanic	3	3	--
White	8	10	--
Other	--	2	--

**Lightness readings by IMS SmartProbe-400 taken at a site not exposed to sunlight (e.g., upper inner arm*

Table 11 presents the information shown in Table 9, this time by constitutive skintone.

Table 11. Descriptive Data and Seasonal Findings by Constitutive Skintone

"L" groups follow Human Skintone Chart (IMS, Inc., Milford, CT); values are medians

		Age	Ht	Wt	BMI	TBBM	Fat	Lean	Fat	BSA*
"L" (lightness) reading	*N*	y	m	kg	kg/m2	g	kg	kg	%	%
Lightest skintone	23	29.9	1.724	66.3	23.1	2301	19.7	51.3	26.1	53.5
Intermediate skintone	39	36.8	1.718	81.2	27.2	2636	19.7	62.0	24.4	43.0
Darkest skintone	24	38.5	1.736	93.3	32.0	2681	24.0	69.4	24.0	32.0

		Intrvl**	25(OH)D nmol/L			Vit D_3 ng/mL		1,25(OH)2D pg/mL		PTH pg/mL	
	N	d	end smr	end wtr	increm	end smr	end wtr	end smr	end wtr	end smr	end wtr
Lightest skintone	23	166	114.0	76.9	37.0	8.9	0.5	35.8	37.0	27.7	33.6
Intermediate skintone	39	154	74.7	48.7	26.0	0.5	1.0	33.8	37.0	29.0	41.7
Darkest skintone	24	149	57.3	33.9	20.3	0.5	1.0	33.4	33.7	28.8	32.9

		serum Ca mg/dL		Ca AbsFx		urine CaCrt g/g		urine NaCrt mEq/g	
	N	end smr	end wtr	end smr	end wtr	end smr	end wtr	end smr	end wtr
Lightest skintone	23	9.4	10.1	0.351	0.312	0.080	0.061	95.3	71.3
Intermediate skintone	39	9.4	9.5	0.300	0.287	0.074	0.054	100.2	74.4
Darkest skintone	24	9.5	9.6	0.276	0.257	0.029	0.031	85.8	87.8

** BSA = sun-exposed body surface area during summer*

*** Interval = days between end-of-summer and end-of-winter visits*

Comment – Reportable Outcomes – Project 2

- Table 9 (data for all subjects) suggests that, although $1,25(OH)_2D$ and serum calcium are unaffected by season, sun deprivation in winter is associated with an increase in PTH and a small decrease in calcium absorption fraction as well.

- The data as presented in Table 11 suggest not only seasonal differences in PTH and calcium absorption fraction, but also differences in these measurements by constitutive skintone.

- As shown in Table 11 (data by constitutive skintone), we found, as have others, that percent body fat is lower among subjects with the darkest skintones. Also, our data show a stepwise relationship between constitutive skintone of the outdoor workers who were our subjects and body surface area that their usual outdoor attire exposed to sunlight: the darker the skintone, the more covered-up the subject. Note as well the clear stepwise relationships between constitutive skintone and both seasonal values for 25(OH)D and estimated summer increment.

Overall Conclusions

- Most adults have suboptimal vitamin D status.
- The degree of inadequacy is directly related to skin pigmentation.
- The most likely explanation is the documented and generally accepted fact that melanin decreases effective vitamin D synthesis in the skin.
- Persons of color, who are most in need of the vitamin D that could be provided from sun exposure, typically expose less skin than do Caucasians when out in the sun. Hence their summer increment is smaller than that of Caucasians for two reasons: 1) their skin synthesis of vitamin D is less efficient; and 2) they expose less skin to the sun.
- Vitamin D metabolism/utilization is not related to skin color; only cutaneous vitamin D synthesis is related to color
- Military recruits of color need, on average, approximately 1000–1200 IU of additional vitamin D each day.
- If it was desired to individualize dosing, the data generated in this study show that serum 25(OH)D would be expected to rise by about 2.8 ng/mL for every 100 IU of vitamin D_3 taken each day by mouth
- This need varies widely, and the above estimate is an average. Some individuals will need 2000 IU/day or more, depending upon their serum 25(OH)D level at enlistment.

REFERENCES

1. Barger-Lux MJ, Heaney RP, Dowell S, Chen TC, Holick MF. Vitamin D and its major metabolites: serum levels after graded oral dosing in healthy men. *Osteoporos Int* 1998; 8:222-230.

2. Heaney RP, Davies KM, Chen TC, Holick MF, Barger-Lux MJ. Human serum 25-hydroxycholecalciferol response to extended oral dosing with cholecalciferol. *Am J Clin Nutr* 2003; 77:204-210.

3. Kratz A, Ferraro M, Sluss PM, Lewandrowski KB. Laboratory reference values. *New Engl J Med* 2004; 351:1548-1563.